RADIATION HAZARDS AND PROTECTION IN DIAGNOSTIC RADIOLOGY*

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Since the discovery of X-ray by Roentgen in 1895, its use in the practice of medicine, both for diagnostic and therapeutic purposes has shown a continued and almost phenomenal rise. Both the advantages and the dangers are of concern to radiologists and physicians in general. The damaging effect on skin in large doses and the more recently discovered production of leukaemia in arthritic patients receiving treatment to spine and in those exposed to atomic explosions, and the evidence that mutations are increased above the normal rate in animals receiving irradiation to the gonads have all emphasized the need for care in the use of this modality. The Canadian Association of Radiologists has recently decided to prepare a code of practice as a guide for the use of X-ray and isotopes in medicine and is following the lead of others in considering a form of registration of all radiation producing sources in an effort to establish a high standard of efficiency which will reduce to a minimum the dosage received by patient and technician without interfering with the best possible results to be gained by this invaluable diagnostic and therapeutic agent.

The recommendations of the International Commission on Radiological Protection contain many instructions on the use and maintenance of diagnostic X-ray equipment. This paper presents experimental data supporting some of these recommendations. We also present a brief report of a small survey of diagnostic X-ray machines across Canada showing how these recommendations are being implemented and pointing out the difficulties in fulfilling some of them.

Recommendation one is that *"The tube protective enclosure should be provided with a diaphragm which leaves a margin of at least 5 mm. of unilluminated fluorescent screen with the screen at its greatest distance from the tube for any angulation of the table"*. The survey shows that this is not always adhered to. One unit checked had shutters adjusted so that the irradiated field was slightly larger than the lead glass for maximum target screen distance. At 95 KVP 3 m.a., the exposure dose-rate was 70 m.r./hour just off the edge of the screen. Since this reading was averaged over a large ionization chamber, it probably is due to a narrow beam of higher dose-rate. This fault has been found several times particularly on older equipment.

Recommendation two is that *"The fluorescent screen shall be covered with a protective glass sheet of lead equivalent of at least 1.5 mm. for 100 KVP"*. Measurements of the transmitted dose through a particular fluorescent screen (with no patient between the target and the screen) were 15 m.r./hour at 89 KVP and 25 m.r./hour at 95 KVP with a tube current of 3 m.a. These figures indicate that this recommendation has been observed.

Recommendation three is that *"The fixed total filter equivalent values should be at least 2 mm. Al and should be based on the value obtained at the highest voltage of the X-ray apparatus. For thick parts of the body of an adult 3 mm. should be used"*.

In order to demonstrate the value of this provision, a water phantom 17.5 cm. thick was used as a patient (a lean and hungry one) and films were placed under the phantom with focal film distance 36″ and focal skin distance 28½″. The exposure in m.a.s. necessary to yield a film blackening of density 1.0 was determined for four different voltages and four different added filters, the inherent filter being 0.5 mm. Al. The skin dose (i.e. the dose to the top of the phantom) for film density 1.0 was also determined. These results are illustrated in figure 1 showing the number of m.a.s. required under experimental conditions to give film blackening of density 1.0. It will be noticed that for KVP's above 75 or 80 KVP, the m.a.s. remains the same for all added filters from 0 to 1.5 mm. Al inclusive.

Dale Trout et al[1] found this same result in a similar experiment. They further found that contrast in films taken of pelvis, lateral lumbar spine, pregnancy films and step wedges was unaffected by filtration at KVP's from 60 to 130 KVP with filters from 0 to 3 mm. Al. One would conclude, therefore, that the use of valuable filtration and the increase in kilovoltage will not result in loss of contrast of the films within the limits stated.
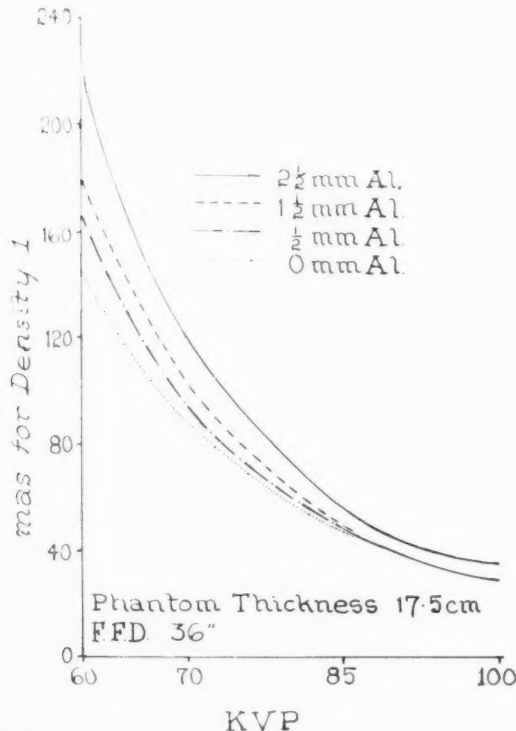

Figure 1

Figure 2 shows the variation in air output with filtration and KVP at a distance from the target of 12″ and figure 3 combines the data of figures 1 and 2 to give the skin dose required under the above geometrical conditions to give a blackening of density 1:0.

Again it should be noted that the phantom thickness was only 17.5 cm. and that many, indeed most, patients would be much thicker, leading to a higher skin dose than that shown in this figure.

The conclusions that emerge from this are:

(a) It is advisable to use a total filtration of at least 2 to 3 mm. of Al. No significant increase in m.a.s. will be required when radiographing thick parts but for extremities it may be necessary to double the m.a.s.

(b) We have discussed only the effect of KVP and filtration on skin doses. While the greatest dose reduction with improved technique is in the skin, it is recognized that, for most procedures, the organs of interest, from a protection point of view lie at a depth, e.g. the gonads and the blood forming organs. Though the effect of KVP and filtration at a depth is not so marked, it is still possible to reduce the depth dose considerably by the proper choice of KVP and filter.

Protection of persons employed in the X-ray room during examination is a matter of concern to all. Radiation is scattered from the patient and from the equipment in all directions, and in Figure 4 we have illustrated an arrangement for measuring this dose scatter to one side of an irradiated water phantom. The target is 50 cm. above the top left hand corner and the irradiated field is 7.5 cm. wide by 15 cm. long. The phantom is 30 x 30 x 16 cm.[3]

The first three results deal with diagnostic and superficial therapy beams. The first one is of doubtful value because of a different geometrical arrangement. The second and third results were taken from a paper by Keane and Spiegler[2]. The last four results are for therapy beams.
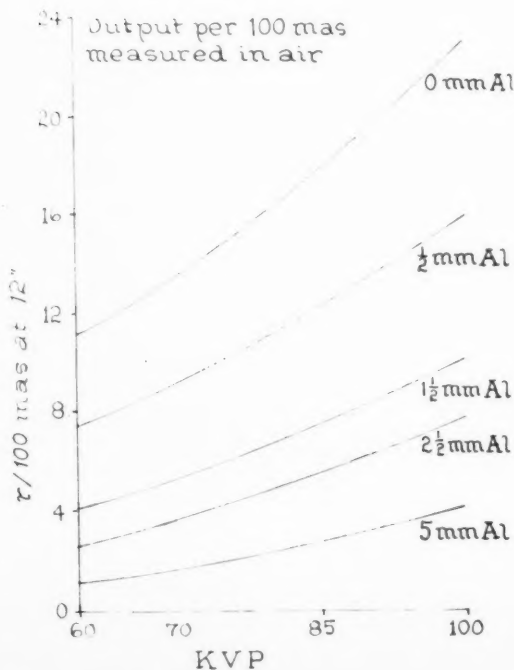

Figure 2

It will be noted that although the quality of scattered radiation from the harder therapy beams is softer than the primary, the reverse is true of diagnostic beams.

Thus it can be seen also that if a technician were to hold a patient during diagnostic procedures he would receive possibly 2 m.r. to 30 m.r. per exposure depending on the technique employed, or up to 300 m.r. during fluoroscopy. For therapy however if a technician held a patient while 300 r skin dose were administered he would receive approximately 1 r if situated 40 cm. from the edge of the field. In practice the values are usually reduced by a factor of 2 or 3 due to absorption of the scattered rays in the patient.
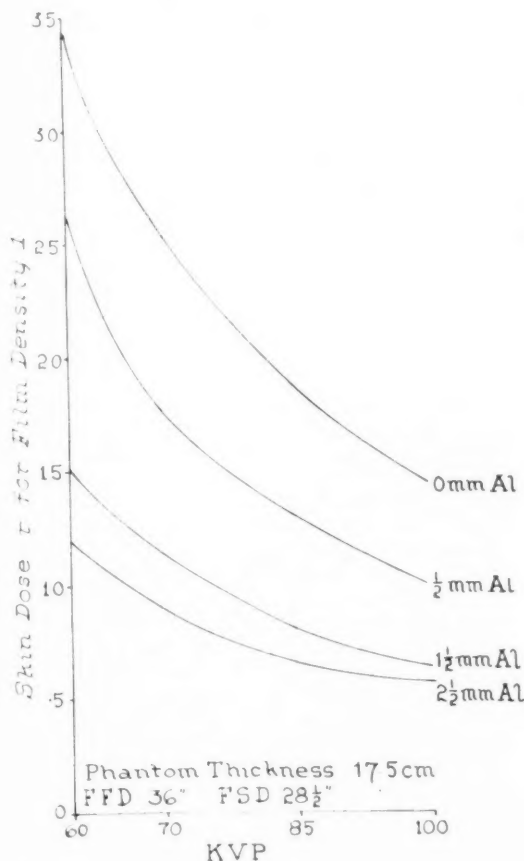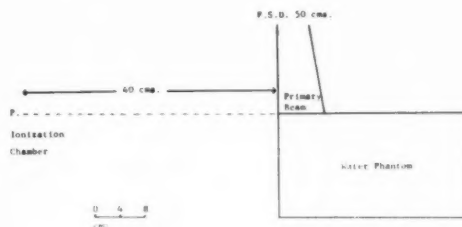
Figure 5 represents the floor plan of a diagnostic X-ray room. The machine was old and defective and has now been replaced by a modern one with better protective devices.

Primary H.V.L.	Scatter H.V.L.	Scatter Dose at P mr/r	Reference
0.8 mm Al	4 mm Al	0.2	3.
1.1 "	2.0	1.5	2.
1.8 "	2.5	2.3	2.
0.6 mm Cu	0.36 mm Cu	2.7	3.
1 "	0.52	3.0	3.
2 "	0.32	3.2	3.
3 "	1.33	3.0	3.

Figure 4

A water phantom was placed on the fluoroscopic table as shown and exposure dose rates were measured at the points indicated for both a large field and a small one. The dashed line marked 'lead' represents a lead screen to protect the technician who stands at 9.
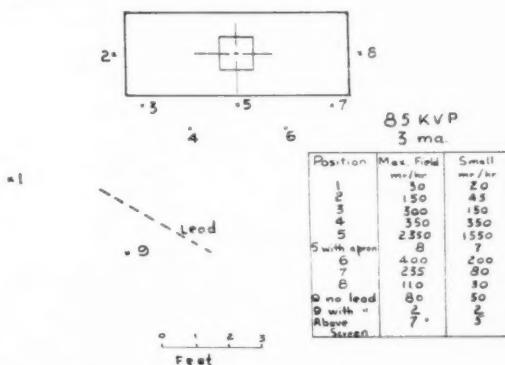

Position	Max Field mr/hr	Small mr/hr
1	50	20
2	150	45
3	500	150
4	350	350
5	2350	1550
5 with apron	8	7
6	400	200
7	235	80
8	110	30
9 no lead	80	50
9 with " Above Screen	7.	2.5

85 KVP
3 ma.

Figure 3

Figure 5

This is the basis for the recommendation that "Persons who regularly work in radiological departments shall not be asked to assist in holding weak patients or children during fluoroscopy or radiography".

Notice that the dose rate at 5, unprotected, reached a value of 2.4 r/hour but the simple expedient of draping a lead rubber apron over the screen and down the side reduced this to .008r/hour. The value of lead protection about the operator is also evident.

This illustrates the worth of the recommendation "That all couches and stands for fluoroscopy are provided with an adequate arrangement for protecting the operator against scattered radiation from the patient. This should take the form of an apron made of three or more overlapping parts to facilitate palpation". It should also be noticed how the scattered dose varies with field size.

Glove	Palm mr	Finger mr	Finger mr	Finger mr
1	76	55	55	50
2	82	38	83	76
3	80	65	71	54
4	106	89	71	75
5	130	133	150	150
6	147	130	122	151
7	288	266	213	162
8	340	236	125	202

Apron	1 Thickness	2 Thickness
1	76	14
2	292	107
3	362	132

5.8 r   100 KVP   no Filter

Figure 6

Finally, the dose transmitted through various types of protective clothing was measured and the results are given in figure 6. All examples were irradiated with 5.8 r of 100 KVP radiation (with no added filter). For the gloves, all afford a fair degree of protection except possibly the last pair, 7 and 8 which looked as though they were designed for driving a racing car. Also all three aprons were adequate, particularly the first, if one were man enough to pick it up. In conclusion, with one exception noted above, all the protective clothing tested was safe for scattered radiation but of course none is completely safe nor is it designed for protection against the main beam.

INFORMATION ABOUT DIAGNOSTIC X-RAY UNIT

1. Make and Model _____ 2. Maximum m.a. _____

3. Years in use _____ 4. Maximum K.V. _____

5. For Overhead Tube:
   (a) Make _____ (b) Added filter _____
   (c) Output in r/100 m.a. at 30 cm. distance from target.
       Measurements made in air with largest cone at: 60 KVP - r/100 mas.
                                                        80 KVP - r/100 mas.
                                                        95 KVP - r/100 mas.

6. For Fluoroscopic Tube:
   (a) Make _____ (b) Inherent filter _____ (c) Added filter _____
   (d) Target to table top distance _____ (e) m. a. _____
   (f) Position of diaphragm system relative to table top _____
   (g) Output in r/min. 2 cms. above table top.
       Measurements made in air with maximum diaphragm opening at:
                                                        60 KVP - r/min.
                                                        80 KVP - r/min.
                                                        95 KVP - r/min.

7. (a) Type of instrument used _____
   (b) Chamber used _____

Figure 7

Survey of Diagnostic Equipment Carried out by the Canadian Association of Radiologists Committee on Standards Units and Protection under the Chairmanship of Dr. E. M. Crawford, Montreal

Overhead Tube   F. S. D. 30 cm.

	Added Filter	Maximum r/100 mas.	minimum r/100 mas.	average r/100 mas.	number of machines
60 KVP	0 mm. Al.	14	7.6*	10.2	6
	1/2	8.1	5	6.4	4
	1	6.6	3.6*	5.3	10
	1-1/2	–	–	4.0	1
	2	5.0	0.5	3.4	33
	2-1/2	3.6	1.4	2.7	14
	3	3.9	1.3	2.4	11
	3-1/2	–	–	2.3	1
	4	–	–	1.0	1
				Total	81
80 KVP	0	20.5	12*	15.2	6
	1/2	13.6	8.5	10.7	4
	1	11.3	5.8*	8.8	10
	1-1/2	–	–	7.1	1
	2	8.2	3.0	6.3	33
	2-1/2	8.0	3.6	5.7	14
	3	7.1	2.6	4.7	11
	3-1/2	–	–	4.6	1
	4	–	–	2.2	1
				Total	81
95 KVP	0	26.0	15*	19.5	6
	1/2	18.0	10.5	13.9	4
	1	14.5	8.3*	11.4	10
	1-1/2	–	–	9.4	1
	2	11.7	6.0	9.1	32
	2-1/2	12.1	6.0	8.6	14
	3	9.7	3.8	6.6	11
	3-1/2	–	–	11.5	1
	4	–	–	3.6	1
				Total	80

* Inherent Filter 1.0 mm. Al.   * Inherent Filter 2.0 mm. Al.

Figure 8

This survey was designed to estimate the range of variation in output of some radiographic machines in use over Canada.

Figure 7 shows the questionnaire that members of the C.A.R. committee were asked to fill out for each machine under their jurisdiction. The questions fall into two groups, first those which anyone familiar with the machine could answer and secondly measurements of output of the machine under standard conditions, 5(c) and 6(g). Figure 8 gives a summary of the results of output measurements on the overhead tube made at 30 cm. for an exposure of 100 m.a.s. at 60, 80, and 95 KVP. For those filtrations, for which there are several readings, it can be seen that the ratio of maximum to minimum output is approximately 3:1. It is to be noticed that of 81 machines reported on, 6 had no added filter. Even this is probably not the true number since some of the machines may have had their filter corrected before the readings were made. The 33 results for X-ray units operating at 80 KVP with 2 mm. Al added filter is shown in figure 9 showing the wide divergence in results between X-ray plants supposedly working under the same conditions.

Figure 10 gives the summary of results for question 6(g) for fluoroscopic units, when they were all corrected to 4 m.a. Again notice the wide divergence between maximum and minimum output readings for similar conditions of exposure. This variation is as high as 6 to 1 in some cases.

These measurements were performed with various types of ionization chambers. In general, however, it can be stated that unless the measuring device has been calibrated against a standard air chamber over the energy range under consideration, the measurements would have little significance.

The survey was very useful since it brought to light many deficiencies which could have been overlooked for long periods of time.

80 KVP   2mm Al. added filter

Figure 9

The first defect that we noticed was an absence of any added filter in two of the fluoroscopic machines examined, this in spite of the fact that the radiologist had ordered the machine with 3 mm. Al filter added. When these two are added to the five already listed in figure 10 we find that 7 out of 39 X-ray machines had no filter and 9 out of 39 had less than the 2 mm. Al. total filter recommended by the International Commission.

Secondly, some of the timers were found to be in error. The output per 100 m.a.s. increased by 40% for the same KVP and tube current when the m.a.s. timer was switched from one range to the next.

The third defect noticed was an error in calibration of the milliampere meter in the fluoroscopic tube unit. We had been assured that this meter was calibrated when the machine was installed only a few months previously and yet when we measured the r/min. delivered 2 cm. above the table our results were as shown in figure 11. The only change made in the equipment was a recalibration of the milliampere meter. There was

obviously an error in the first calibration. Fortunately the error was on the safe side.

UNDER TABLE TUBE

Fluroscopy at 4 ma.

	Total Filter	Maximum r/min.	Minimum r/min.	Average r/min.	Number of machines.
60 KVP	½ mm. Al.	12.0	2.7*	7.4	4
	1	10.5	4.9	7.7	2
	2	5.0	3.3	4.0	4
	2½	2.8	1.7	2.3	6
	3	6.7	1.0	2.9	9
	3½	3.3	0.6	1.8	13
80 KVP	½	20.5	6.7*	14.2	4
	1	18.5	8.0	13.2	2
	2	8.4	6.2	7.1	4
	2½	6.3	3.3	4.4	6
	3	13.3	2.0	5.2	9
	3½	6.0	1.3	3.4	13
95 KVP	½	32	8.3	19.8	4
	1	21.8	9.6	15.7	2
	2	13.0	9.3	10.7	4
	2½	8.5	4.0	6.5	6
	3	16.0	2.5	7.1	10
	3½	9.3	1.8	5.0	13

* 30" Target to Table Top Distance

Figure 10

Other faults that may come to light during the examinations of equipment include faulty diaphragms and faulty centering of the target. Defects in diaphragming are readily observed by the radiological staff and should be constantly checked. The staff may also examine filters in the overhead tube and in the under table tube. The role of the technician in reducing dose to the patient is most important. It is a matter of simple arithmetic to see that if a film is improperly taken and must be repeated, the patient's dose is multiplied by 2. Thus care in the first place on the part of the technician is one of the greatest weapons in the reduction of dose to the patient.

	r/min		
	60 K. V.P.	80 K. V. P.	95 K. V. P.
Before Repair (3ma.)	1. 48	1. 97	1. 65
After Repair (3ma.)	1. 55	2. 94	3. 96

Figure 11

Recommendations

In conclusion, we recommend:

1. Adherence to the recommendations of the International Commission on Radiological Protection.
2. Adequate survey of equipment to discover defects in operation. This will require careful calibration of the measuring device.
3. Meticulous care by the diagnostic technician to avoid necessity of repeat examinations.

REFERENCES

1. Trout, E. Dale, Kelley, J.P., Cathey, GA., The Use of Filters to control Radiation Exposure to the Patient in Diagnostic Roentgenology, Am. J. Roentg. and Radiation Therapy, 67, 946, 1952.

2. Keane, B.E., and Spiegler, G., Stray Radiation from Diagnostic X-ray Beams, Brit. Journ. Radiology, 24, 198, 1951.

3. Holloway, A.F., — to be published.

POSITIONS AVAILABLE

Assistant Radiation Physicist required for fields of Clinical Diagnostic and Therapeutic Radiology and Nuclear Medicine in large general hospital. Minimum qualifications B.Sc. with major in Physics; M.Sc. in Physics preferred. Experience in medical application of physics desirable but not essential. Applicants should submit curriculum vitae, earliest date available, names of two references and indication of salary expected with letter addressed to:

> The Radiologist-in-Chief,
> for attention of the Radiation Physicist,
> Royal Victoria Hospital,
> Montreal 2, Canada.

Assistant Radiologist certified in diagnosis, or eligible for certification within the next year, required. 450 bed general hospital. Modern X-ray Department with most up-to-date equipment. Apply with full particulars to Radiologist, McKellar General Hospital, Fort William, Ontario.

Radiologist wanted immediately to service two hospitals in the center of the Annapolis Valley. Hospitals are: Western Kings Memorial Hospital. Berwick, N.S., with bed capacity of 40 and extension under consideration, and Soldiers' Memorial Hospital, Middleton, N.S., a new 68 bed, opening in Spring 1961 replacing present 27 bed structure. These two towns are twenty miles apart, all paved highway. Income commensurate with qualifications. Address reply to: The Superintendent, Soldiers Memorial Hospital, Middleton, Nova Scotia.

Radiologist certified in Diagnostic and preferably in Therapeutic Radiology as well. Well setup department. Excellent medical staff. Write Dr. A. M. Edington, Victoria Public Hospital, Fredericton, N. B.

REQUISITES FOR GOOD X-RAY CINEMATOGRAPHY

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There have been many discussions as to what type of equipment will give good results for X-ray cinematography. Much importance has been attributed to different quality of films, different types of processing and especially the size of the recording cine-camera. For ten years there has been an uncertainty as to whether it is necessary to use a 35 mm. camera for adequate recording or whether 16 mm. is sufficient. Lately some angio-cardiologists have considered using 70 mm. film for recording images from the output phosphor of a 9″ image intensifier[1]. The reasoning is that if the best films available from 5″ intensifiers are done with 35 mm. cameras, 70 mm. recording cameras are necessary for 9″ image intensifiers. Comparative cine-films of the same object with a 5″ or a 9″ image intensifier and a 35 mm. camera, show that better resolution is obtained with the former. This reasoning leads to the conclusion that for best results a 70 mm. camera should be used with a 9″ intensifier.

We believe that the problem lies much deeper than in the resolving power of 16, 35, or 70 mm. films, and our observation of the work done by different workers suggests that it is not the type of equipment used, the size of the camera and the resolving power of the film that count, but the perfection to which the technique has been evolved with the equipment used.

For instance, we do not think that using a 35 mm. camera without a grid will give us a better angiography than using a 16 mm. camera with a grid. Factors such as this contribute so much that the over-all effect in quality is in the last analysis dependent for the least part on the equipment used and for the most part on the way it is used. Dr. J. A. Campbell of Indianapolis[1] has pushed this reasoning to quite an extent. He works with a mixed selection of every available image intensifier and cine-camera; the end results are quite comparable. Considering the problem as a whole, we believe the following represent some of the requirements of X-ray cinematography.

1. **X-ray Factors**
    (a) High Kv
    (b) Grid
    (c) Diaphragms
    (d) Centering

It is important to have the best X-ray beam available for a particular type of work. We think that high Kv will help in abdominal work. Also, a grid is useful when large fields are necessary or when working with large patients. When working with the 9″ image intensifier, a carefully colimnated beam should be used as much as possible, since the secondary rays in a large field have an important fogging effect. It is also important to keep the X-ray beam very well centered to the image intensifier.

2. **Image Intensifier**
    (a) Spot
    (b) Centering

It is important to eliminate the spot which is present in poor image intensifiers or old image intensifiers. In some 9″ image intensifiers, there is an electron vacuum system which can be activated once in a while and which will permit the removal of the tiny spots and prevent the formation of large spots.

At the Jean Talon Hospital, the vacuum device is used once a week from 5 in the evening till 8 the next morning and always on the same day of the week. As is well known, the intensifying factor and the contrast in the image depend on the vacuum of the tube. During the operation of an image converter tube some gas molecules can always be freed. Although the number of gas molecules freed is extremely small they can spoil the vacuum over long operating periods. In Philips Image Intensifier tubes, this risk is eliminated by a built-in "electronic getter" which binds the gas molecules. The vacuum in the image intensifier tube is thus kept constant during its entire life. (Manufacturer Advertising 58.054 B E6/59.) At all times the relation of the X-ray beam to the center of the image intensifier should be perfect. With our equipment a 15° deviation of the tube can occur without being noticed, so that periodic checks are necessary.

3. **Lenses**
    (a) Good lenses
    (b) Fast lenses

No effort nor expense is too great when it comes to having very good and very fast lenses. All lenses have aberrations, but the

better ones have less and this will reflect in
the film quality. It is essential to eliminate
as much of the peripheral blur as possible.
It is important to have fast lenses since they
will make the difference between over-ex-
posure of the patient and acceptable exposure.
As an example, a lens of f 2.0 will require
approximately four times more radiation than
a lens of f 0.8, and nowadays fast lenses are
available, or can be manufactured when not
available, for the type of camera used. With
our 5″ amplifier we have a system of f 1.02
with no appreciable peripheral blur and we
think that the same should be procurable
with 8″ and 9″ intensifiers.

4.   Camera

    (a) Sturdiness

    (b) Large loading capacity

    (c) Variable speed

It is most gratifying to use a camera for
three years, as we have done, without a break-
down of any kind for accidents will happen
with a cine-camera which is repeatedly
attached and removed from an image intensi-
fier. We have dropped our camera four feet
to the cement floor and it has continued
working without any noticeable damage. A
high quality, sturdy camera therefore is im-
portant if the equipment is to be used daily.
It is also, we think, very important to procure
the type of camera which can be loaded with
adequate length of film. When doing much
gastro-intestinal work, one hundred feet of
film is insufficient for a busy unit and the
operator is frequently interrupted for film
reloading, whereas four hundred feet of film
will do from eight to twelve gastro-intestinal
series, depending on the importance of the
studies.

The camera should have many speeds to
choose from. We use ten frames per second
for duodenal series, thirty frames per second
for esophagus or angiography. We have a
film speed range from six frames per second
to sixty frames per second, our main use of
the camera being gastro-intestinal, we save
much film being able to do slow recording and
at the same time give the patient less radia-
tion.

5.   Film Selection

    (a) Cineflure

    (b) Tri-X

    (c) Plus-X

    (d) Shellburst

    (e) Cine-Ray

This is a much discussed subject. We are
familiar with four films: Cineflure, Tri-X,
Plus-X, Shellburst. Cineflure is a fast and

contrasty film; quite suitable for X-ray cine-
matography. It has the disadvantage of being
very grainy and when copied it cannot be
improved. Tri-X is a fast and a contrasty
film, not as grainy as Cineflure; it comes

Figure 1 — Enlargement of 16 mm. Cine Strip.

either as a reversal or as a negative film.
The reversal film has the advantage of being
some 20% faster than the negative film and

the positive copy it gives is easier to interpret than the negative film. Plus-X is a medium speed film; it has a medium contrast and a low grain. It gives very gratifying results, especially when used with a grid and has the advantage of being handled by a Logetron copier without too much grain being added. Up to now, we have preferred it to any other film. Shellburst in our hands has shown a low speed, a low contrast and much grain, in other words we have to use more radiation to have a lower contrast film which is quite grainy. We know some people use it with very good results. We cannot work it to a satisfactory result and we have abandoned it until somebody can teach us how to handle it. Cine-Ray is a film we have seen used by others with very good results, one month of experience with Cine-Ray makes us conclude that it is in the class of Plus-X.

6. Processing

    (a) High gamma
    (b) Sufficient developing time
    (c) Cleanliness
    (d) Preservative

Processing can make or break a film. One of the important recommendations made at the first American Symposium on Cineradiology in Rochester[2] to obtain results of good contrast with X-ray cinematographs is the use of high gamma solutions; the figure quoted in Rochester was a gamma of 1.5. X-ray developer happens to be a solution which will give a very high gamma.

We have been concerned whenever our results were not quite as expected and we therefore procured a densitometer. γ (gamma) is a quantitative photographic measure of the contrast obtained with processing. If we expose a film with twenty different doses of X-rays or with a penetrometer we should optimally obtain twenty shades of white, gray and black. Let us say that in one instance using fine grain developer we obtain ten shades of white, gray and black and that using X-ray developer we obtain five shades of the same color scheme. Then we will know that X-ray developer gives higher contrast and that the γ is more elevated. To check the γ we use a densitometer and read the density of the different shades appearing on a film which has been prepared with different exposures to light. These readings are plotted against the number of shades obtained and the angle obtained by the straight portion of the curve is the γ where tg $45° = 1.0$. Usual figures for commercial photography run from 0.5 to 0.6. We get 1.3 with Plus-X film and X-ray developer at 68° F.

For good results, we think that good and fresh solutions should be used as much as possible, and that sufficient developing time should be given, and in this respect certain type of processors appear inferior.

It goes without saying that the film should be fixed adequately. Cleanliness and quality operations should be respected. For very special films which will require copying or improvement through techniques such as Logetron, there are some film preservatives which will harden the emulsion, preserve it from scratches and retain the finish for very long periods[3].

7. Resolution Tests

Working day after day with equipment it is difficult to judge whether improvements or regressions are taking place with technique. It has recently occurred that judgment of an image can be very inexact when done qualitatively without any quantitative criteria. Since then we have looked for an easy day-to-day check of the results under comparable operating conditions. We have come to the conclusion that a check with ordinary screen mesh which has 6 lines to the centimeter can be made and compared from time to time. First the general impression of the definition of this mesh can be done before studying the production of the day and it can also be compared with what was done 1, 2, 3, 4 months and a year before in the same experimental conditions. We now do it routinely.

Conclusion

It is not possible to do amateur cineradiology; no corners can be cut. Only good work is acceptable. If the principles of cinematography are not absolutely respected the results will be poor and higher radiation exposures than necessary will result. There is an opinion expressed often that cineradiology is a strictly functional approach to the problems and that the individual frames cannot be studied with the hope of finding detail. This is partly false. When good cinematography is achieved it has good definition, and if radiologists are ready to use as much energy in the technicalities of this new discipline as they do with their conventional work they will be rewarded with very gratifying results.

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ISOLATED TRACHEOESOPHAGEAL FISTULA DEMONSTRATED
BY CINEFLUOROGRAPHY

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Isolated congenital tracheoesophageal fistula without oesophageal atresia is still considered to be a rare disease although it is being demonstrated with increasing frequency by careful radiologic examination. Now that it is amenable to surgical treatment, its accurate and early diagnosis is of the greatest

Case Reports

Case I, J.B., female, age 6 weeks.

This was a full term infant born following uneventful pregnancy, and appearing normal at birth. Two older female siblings are alive and well and there is no history of parental consanguinity. During the first month several episodes of choking

Figure 1 — Case I, 10 serial frames of cine study showing the fistula by injection of barium mixture into oesophagus by catheter.

importance. We wish to present two cases in which the diagnosis was particularly difficult because of the high position of the tracheoesophageal fistula, which was in the neck in each case, and in which the use of cinefluorography made demonstration of the fistula possible.

during feedings were reported. A physician saw the infant at age 6 weeks, and because of the choking on feeding, diagnosed tracheoesophageal fistula. The patient was admitted to the Montreal Children's Hospital the following day. Physical examination on admission revealed no abnormality. During the first hospital day a two-ounce feeding of milk formula was given and lead to a sudden attack of cyanosis and respiratory arrest. The use of suction in the upper respiratory tract and administration of oxygen were quickly effective in restoring normal respiration and colour. Radiographs of the chest were normal. A barium examination of the oesophagus by the method that will be described showed that the swallowing mechanism

was not normal, with poor initiation of deglutition and ineffectual oesophageal peristalsis. Some barium was seen to enter the trachea, but no fistula was seen on fluoroscopy or recorded on the spot films made during the procedure. The cine study, exposure rate 30 frames per second, was interpreted as showing no fistula although in retrospect it was briefly shown once. Laryngoscopic an oesophagoscopic examinations were done and revealed no abnormality. Two more cinefluorographic studies were done and again the demonstration of the lesion was made on some of the direct injections into the oesophagus through a catheter (Fig. 1) while other injections showed no abnormality. A definite diagnosis was then made of a fistula at the level of the 7th cervical vertebra, and study of the cine films showed that it was about 2 to 3 mms. in diameter and 5 mms. long, and that it passed from the anterior wall of the oesophagus upward and anteriorly to the posterior wall of the trachea.

been asked to be present during this procedure, restored respiration to normal. Chest radiographs made during the following day showed an abnormality for the first time, barium being identifiable in moderate amount in both lungs. No further episodes of respiratory difficulty occurred, and the child's condition was satisfactory following this alarming episode of aspiration. Two days later, a thoracotomy was done. The fistula was exposed through a high chest incision, and ligated and divided. The post-operative recovery was uneventful. When last seen at the age of 6 months the child was growing and developing normally without further difficulty in breathing.

Case II, W.C., male, age 4 months.

This infant was born at term following a normal pregnancy, and appeared normal at birth. Two older brothers and a sister are alive and well and there

Figure 2 — Case II, 10 serial frames of cine study showing tracheotomy tube and first passage of barium mixture into the fistula.

No more than 20 frames of each diagnostic injection showed the fistula and this event would elapse in approximately two-thirds of a second. This diagnostic investigation occurred over a period of 13 days. By the end of this period the pharyngeal and oesophageal inco-ordination was no longer evident fluoroscopically. In the meantime feedings had been administred through a nasogastric tube and the child had done well. During the last cineradiographic study a total of 70 ccs. of opaque medium was used, and toward the end of this examination, vomiting occurred. A considerable amount of the opaque medium passed from the stomach up the oesophagus, through the tracheoesophageal fistula, and into the trachea. The infant became blue and respiration ceased. Rapid suction of the trachea by Dr. H. T. Davenport‡, who had

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is no history of parental consanguinity. During the first three months of life, there were repeated respiratory infections. At age three months an upper inspiratory infection occurred which was sufficiently severe to require admission to another hospital. In hospital, bronchopneumonia was diagnosed and treated, but while recovering he developed laryngitis, and a tracheotomy was performed. The tracheotomy tube was removed several days later, and the child was then transferred to the Montreal Children's Hospital. On admission examination, the infant was pale, appeared chronically ill, and showed respiratory distress with marked sternal, intercostal and suprasternal indrawing. The breath sounds were harsh, the air entry into the chest was poor, and there were fine rales on auscultation of both lungs. Because of this obvious respiratory distress, a second tracheotomy was performed on the second hospital day. This caused considerable improvement in the patient's condition, but there was still noisy respiration suggesting

excess mucus in the upper respiratory tract. Vomiting frequently occurred following feeding. Suction of the upper respiratory tract through the tracheotomy tube was frequently necessary because of respiratory difficulty. Chest radiographs showed widespread bilateral pneumonia. Because of the history of repeated respiratory infections, vomiting, and excess fluid in the upper respiratory tract, a search for tracheoesophageal fistula was recommended, but could not be performed until the fourth hospital day because of the child's poor condition. A thin mixture of barium sulphate was given by mouth, and some of the opaque medium was seen to enter the trachea, but the route of entry was not identifiable fluoroscopically or on spot films. Later the same day a second attempt was made, using cineradiography, to determine the mechanism of aspiration into the trachea. The cine film was exposed at 30 frames per second, with the infant in lateral projection, and barium mixture was injected into the oesophagus through a catheter. A fistula was clearly demonstrated by the cineradiography, passing horizontally from the oesophagus to the trachea at the level of the first dorsal vertebra. It was estimated to be 2 mms. in diameter and 4 mms. in length and the fistula was shown on 70 frames of the cine film, indicating that its visualization had occurred during approximately 2 seconds, (Fig. 2). On the fourteenth hospital day, at age 5 months, a thoracotomy was done. Through a high chest incision, the trachea and oesophagus were exposed. The region of the fistula was visualized with difficulty because of fibrous tissue which was likely secondary to the two previous tracheotomies. Suture of the fistula in continuity was done because of difficulty in visualization. Following the operation, the patient had a long and stormy postoperative course complicated by pneumonia, dependence upon the tracheotomy tube, paralysis of the right leaf of the diaphragm, and otitis media. Six weeks after operation the tracheotomy tube was successfully removed. Two more cinefluorographic studies of the oesophagus were made after the operation to be sure that the fistula was closed, and in each study a blind pouch anterior to the oesophagus was found but no contrast material entered the trachea. Recovery occurred from the diaphragmatic paralysis, the otitis media cleared, and the child was discharged in satisfactory condition.

Discussion

We have searched the literature on congenital tracheoesophageal fistula, but a complete review of all the published articles will not be given here, since full reviews are available in recent publications[1,2]. A full bibliography is appended and over 70 cases have been well documented. The present case reports do not include the entire experience with tracheoesophageal fistula at this hospital[7,26], but are being reported separately because of their occurrence in the low cervical area, and because of the interest and importance of demonstration by cineradiography. Congenital tracheoesophageal fistula may be found in almost any age, but is most frequent, and its diagnosis and treatment most important, in very early life. The usual clinical features are coughing, choking and cyanosis after each feeding of the newborn. There may be excessive mucus in the nose, mouth and pharynx, and the abdomen is usually distended by air which has entered the

oesophagus through the fistula. Pneumonia occurs readily and frequently because of the aspiration of food and secretions through the fistula. If the patient lives long enough to begin taking solid foods, it is generally found that they cause less trouble than fluids because of the small size of most fistulas. Moreover the symptoms and signs caused by fluid ingestion may be intermittent, presumably due to occasional plugging of the fistula by mucus or food.

If the condition is unrecognized there is constant danger that death from asphyxia may follow a feeding, or be caused by aspiration pneumonia and its complications. The older the patient the less striking the symptoms and signs are likely to be, but even in the occasional adults successfully diagnosed and treated, there has sometimes been a surprisingly characteristic history[1,2,4,9].

The anomalous communication has been found at all levels of the trachea from the second ring to the bifurcation, but occurs in the cervical area in only about 20% of the cases[1,2,3,11,12,14,15,17,18,20]. At this level, because of the rapid passage of opaque medium through the upper oesophagus, the movements associated with swallowing, and the complicated anatomy of the junction of the hypopharynx and trachea, the diagnosis tends to be particularly difficult. Of a total of 13 cases reported where the fistula was in the neck or at the junction of the neck and thorax as in our cases, 6 have been successfully identified and treated during life. As in our Case I the fistula characteristically has a lower oesophageal than tracheal orifice. The diameter may vary from a lumen of pinpoint size to several millimeters, and the length varies from a "window" opening to a length of several centimeters. The tracheal opening tends to be the same diameter as the mid portion of the fistula while the oesophageal orifice is generally larger and funnel shaped. Because the oesophagus is slightly to the left of the trachea, the usual course is slightly oblique from left posterior to right anterior, as well as from lower posterior to upper anterior. There are two published cases in which two separate fistulas were present in the same patient[3].

Diagnosis

The problem of diagnosis has been discussed by several authors[24-33] and a number of suggestions have been made for improving diagnostic accuracy. Kirkpatrick[29] has particularly recommended cinefluorography in the study of infants who have had operative anastamosis done for congenital oesophageal atresia, and who may develop a secondary fistula. In general it would appear that the higher the level of the fistula and the smaller

its lumen, the greater is the difficulty in demonstrating it by radiologic methods. The rapid pharyngeal and upper oesophageal movements during swallowing, and the coughing caused by passage of swallowed fluid into the trachea, both contribute to confusion when the high fistula is studied by fluoroscopy and spot films. Thus in our cases the filling of the fistula by contrast medium was rapid and transient in each patient, in Case I occupying about two-thirds of a second and in Case II about two seconds. The advantages of the cine method with slow motion or single frame film analysis are therefore evident.

Other methods of demonstration of the anomalous communication between trachea and oesophagus have been recorded or recommended in the past[25,27,28,30-33], and they include oesophagoscopy or tracheoscopy with visualization, a fistula orifice, or visualization of air bubbles or coloured dye or a mixture of opaque medium and dye passing from one structure into the other under direct vision. The accidental passage of a catheter through the fistula and its subsequent visualization by chest radiographs has also been recorded. All these methods, while useful, would seem to be on the whole less satisfactory than radiographic demonstration, providing it can be done safely. In this connection it is our practise to work closely with the Department of Anaesthesia, and when an examination is undertaken on an infant about whom there is any concern, a physician from that department attends. The value of this co-operation was dramatically demonstrated in our first patient (Case I), who vomited toward the end of the procedure and was in grave danger of dying immediately from asphyxia, had rapid laryngoscopy and direct aspiration not been carried out.

Our method of administration of the opaque medium and the choice of opaque medium have been described elsewhere[26] as has our investigation into the effects of various media on experimental animals. We believe that an infant or young child who is suspected of having a disorder of swallowing mechanism or tracheoesophageal fistula should first be investigated radiologically by catheterization of the oesophagus and direct injection into the lower, then mid, then upper oesophagus, preferably using Dionosil. This injection is done gently but sufficiently rapidly to slightly distend the oesophagus, and appears to be highly reliable, particularly using cineradiography, in the diagnosis or exclusion of a fistula. If none of the opaque medium enters the trachea during the direct oesophageal injection, barium is given by mouth and the swallowing mechanism carefully examined. It should be emphasized that there are many young infants in whom swallowing is difficult or inefficient and associated with passage of swallowed fluid into the trachea. Many of these infants have a disorder of swallowing which is primarily one of inco-ordination[24]. The disorder of swallowing will frequently resolve within the first few weeks or months of life. It is the separation from this group of the uncommon but important patient with congenital tracheoesophageal fistula which presents a challenge in diagnosis and an opportunity in surgical therapy.

Case II presented with a less characteristic history of congenital tracheoesophageal fistula, and had two separate tracheotomies before the final surgical closure of the fistula. The fistula itself was the unusual horizontal rather than the commoner oblique type, as shown by X-ray examination, and at operation was difficult to identify because of fibrosis. For these reasons we cannot be certain that it was a congenital rather than an acquired fistula, though its straight smooth contours and uniform size as shown by X-ray are very much in favour of a congenital fistula. In any case its significance to the patient was not different from that of the typical congenital lesion in Case I.

Summary

Cinefluorography has been used to demonstrate isolated high tracheoesophageal fistula in 2 infants, and in both cases identification of the fistula was followed by successful surgical treatment. The cinefluorographic method of diagnosis with injection into the oesophagus of opaque medium appears to be accurate and particularly useful in high fistula where diagnosis by other methods has proved difficult. We have been impressed by the importance of co-operation between the Departments of Radiology and Anaesthesia during X-ray examination of infants with respiratory difficulty during swallowing.

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BOOK REVIEW

The authors have achieved their objective of presenting the basic knowledge of clinical nuclear medicine. Physicians who refer their patients to an isotope laboratory or those who are beginning to train in a laboratory, will find this book very helpful. Its strength is in its two main parts on diagnostic methods and therapeutic applications. A clear text and helpful illustrations enable one to follow the principles easily and to gain perspective. All of the developed techniques are considered in proportion to their value.

At the same time, the book is not a complete review of the field as the title "Practice" might imply. For example, in the chapter on the diagnostic tests of thyroid function one grasps the basic principles easily but there is no discussion of the tracer doses to be used, and the chapter on treatment of hyperthyroidism does not outline the immediate procedures to be used in the event of accidental overdosage. The radiotherapist will be most interested in the three chapters on the use of radiophosphorous, radiocolloids, and implanted radioactive sources. These subjects occupy about one seventh of the volume of the book and each chapter is an excellent orientation essay in the use of the agents. The active worker in the field will be disappointed if he wishes to compare his technical and clinical problems to the experience of the authors as these matters are not discussed.

Skill in the use of radio-isotopes is gained only by a clear knowledge of the patients that one tests or treats. The book that unites the patient's problem and the isotopes that are used to help in its solution has yet to be written. In the meantime, the authors enable one to obtain an understanding of nuclear medicine in this easily readable and lucid book.

D.M.E.

FACTORS DETERMINING QUALITY IN A RADIOGRAPH
with a Discussion of Film Faults and Artefacts

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PART II

IX. ARTEFACTS AND FILM FAULTS

An artefact is defined as an artificial product *(L. arte, by art; factum, made)* or any change that is unnatural or due to manipulation. As applied to radiography it covers a tremendous variety of film faults and flaws in the finished product. It is an unusual radiograph which does not exhibit one or more blemishes but it can be held to be rare indeed that the cause is in the film as received by the X-ray department.

Space does not permit one to list all the faults that one might encounter. It is even difficult to prepare a suitable classification. Some artefacts such as static electric marks, abrasions and light streaks are so common that every radiologist recognizes them in their usual form. They may however make a pattern not at all obvious. Some make intriguing oddities easily recognized as not representing pathology in the subject but difficult to track down as to cause. Recognition that one is dealing with an artefact is first in importance lest errors in diagnosis be made.

Apart from the usual method of scanning radiographs there are six extra procedures to follow for general interpretation and for the detection of artefacts:

1. Mask uncovered portions of the view box.
2. Trace each unusual line or shadow whose nature is not readily apparent to its extreme ends.
3. Examine both sides of the film by oblique reflected light away from the view box.
4. Use a spot-light to look at all opaque areas too dense to be interpreted with the view box.
5. Examine unusual shadows with a hand lens.
6. View the film from an increased distance.

One might consider artefacts under four broad headings:

A. Processing faults.
B. Faults arising during exposure.
C. Inherent film faults.
D. Miscellaneous.

A. Processing Faults

(1) *Static electricity*

The marks of dry atmosphere static electricity when tree-like in shape are readily recognized. Less obvious are those which are smudges or simply linear. Distinction of the linear variety from a fracture line may be made when the line is darker than it would be for a fracture of the width shown. Suspicion of the spurious nature of the mark may be given by the lack of demonstration in other views. A stereoscopic mate is often helpful here. Further, one may find that the line in question may actually lead into the soft tissues.

A metal strip which grounds the surface of the loading bench will reduce the frequency of static marks if they cannot be controlled by a humidifier.

Figure 1 — Desensitization or sensitization produced by the pressure of pencil writing on paper placed over the film depending upon whether pressure was made before or after X-ray exposure.

(2) *Pressure and kink marks*

Pressure effects and kinking of the film over the thumb-nail cause the familiar short arc artefact which is sometimes in the shape of a bow and arrow. It may be palpable and with oblique reflected light one may see the kink in the film. Ordinarily these marks are darker than the surrounding portions of the

film for the emulsion is locally sensitized by the pressure. However it may result in depression of sensitivity and produce a lighter area. By experiment it has been found that pressure before X-ray exposure produces desensitization and light lines, whereas pressure after X-ray exposure produces sensitization and dark lines. Figure 1 illustrates these two forms.

(3) Abrasions

Abrasion of the emulsion may produce a lifting of the surface which is readily seen and felt. Frequently however it sensitizes the emulsion and makes a dark streak which is deceptively like a fracture line. Oblique viewing by reflected light may demonstrate conclusively that it is an artefact.

Figure 2 — Gravitational streaming of products of development. Dark streaks up to 2" long extend below relatively unexposed areas beneath the film marker. Note that they are longest in relation to the longest vertical component of the lead letters.

(4) Finger marks

Grease from lotions and creams is readily transferred to films and by preventing development results in areas of lightened density. An image is still present as usually the emulsion of only one side is affected. Fingers contaminated with fixing solution or developer may leave impressions on the film where development is retarded or accelerated as the case may be.

(5) Development mottling

Mottling due to irregular development may arise if development time is curtailed. Agitation during development does not always correct this fault which is more apparent in thin under-exposed films.

(6) Gravitational streaming

Gravitational streaming of products of development produces streaky marks which run vertically downward. They are usually dark toned and seldom cause confusion if one is familiar with their nature. They are produced by slow currents in the developer which is locally stronger and heavier and less exhausted below areas which have received less exposure. They are often noted adjacent to lead markers. An undisturbed developer is essential for their formation (Fig. 2). The streamers are longest in the areas below the longest vertical component of the lead letters. An example has been seen in which these shadows were adjacent to a metallic foreign body and resembled gas in the soft tissues.

(7) Bromide drag

A somewhat similar effect to gravitational streaming but light in tone instead of dark, is produced by release of bromide in development of heavily exposed areas. This may be termed "bromide drag" as bromide ions have a depressant effect upon the developer. In conventional photography this may take the form of a halo known as the "Mackie line"[2]. Here again agitation prevents this fault.

(8) Film contact

Contact of two films in the developer will retard or prevent local development and result in a light patch that is usually round or oval. The defect is the same on each film. Since X-ray films are double coated there is still a subject image in the affected area. This type of fault is especially a hazard if the two films making contact are mates, such as frontal and lateral views of a region. (Figs. 3(a) and 3(b).) The unsuspecting viewer will usually interpret the "lesion" as a mass. An artefact may not be considered as a cause for the supposed pathology since it is shown in two films and localization can be made in three planes. Recognition of this variety of blemish will be made readily if the routine of inspecting the film by oblique reflected light is followed. One will see it as a shiny area, for the film contact produces a glazing effect much as a ferrotype plate puts a gloss on prints. Occasionally the gloss is scarcely recognizable.

(9) Fog

Reference has been made to several varieties of fog in its effect upon contrast. We are here concerned only with fog introduced in the dark room in handling and processing film.
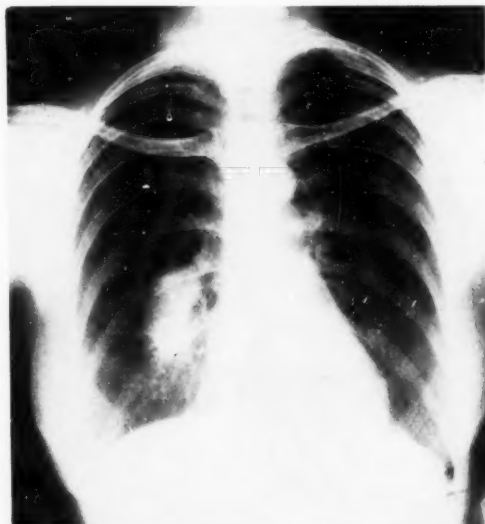

Figure 3(a) — Film contact artefact. Frontal view of chest showing a large light patch in the right lung field suggesting a mass.

Figure 3(b) — Lateral view of the same chest. The supposed mass is further identified as to position.

Dark room lights may be unsafe because of deterioration of the filter, a leak in the supposed light-tight lamp house or an overly strong bulb. Safety in dark room illumination is a relative thing — time and intensity determine the safety level for a particular filter and film combination. Many dark rooms are excessively dim. One should have all the illumination that safety permits.

Reference has already been made to developer fog and stain. Coal gas, and fumes of turpentine, benzol or hydrogen sulfide readily cause fog in stored films. Another form of fog is dichroic or two-toned. This is a colloidal silver deposit greenish yellow by reflected light and pink by transmitted light. It may occur in the developer or fixer, usually in the latter as the result of accumulation of developer to the point of exhaustion.

Fog from aerial oxidation of the developer may occur if the film is too long removed from the developing tank for inspection. This may be coupled with fog from the safelight.

(10) Reversal

Reversal of image tones which may occur in conventional phatography from gross overexposure does not take place from radiographic exposure alone. However reversal is occasionally seen if the dark room light is turned on before development or fixation is complete. Development proceeds for a while with the first image acting as a partial screen for the undeveloped silver still present in the emulsion which then forms a second image with opposite densities.

(11) Reticulation

Reticulation is a wrinkled pattern in the emulsion usually caused by an abrupt change in temperature from one solution to another. The expansion and contraction of the emulsion exceeds that of the base resulting in this peculiar appearance resembling leather grain. Lack of hardening in the fixing solution may lead to this fault when washing is done with cold water. In ordinary photography, reticulation is a major cause for lack of definition but it often requires magnification to be recognized.

(12) Opalescence

Temporary opalescence of the emulsion may be seen with fresh concentrated fixing solution. It is due to dehydration and fortunately disappears with washing and drying.

(13) Inadequate washing mottle

Incomplete washing is readily recognized in its marked form for there may be a powdery surface deposit of chemicals. In mild cases there is no surface deposit but instead a wavy variation in opacity which may suggest a pathological condition.

Few radiographers are aware that a reduction in total processing time may be realized by deliberate slowness in lifting films from one solution to another. With a slow transfer,

surface tension wipes the film surface effectively and the time spent in holding the film completely out of the tank for drainage is much reduced. This procedure has the merit of reducing contamination of solutions and is a worth-while economy measure as well.

(14) *Water marks*

Water marks from the drying of droplets that have not drained away appear as a pattern of rounded light areas with darker borders resembling ostrich leather. There may be a central ringed area as well. Abnormalities such as gall stones may be closely simulated. Sometimes the long single track of a large drop of water dislodged from the film hanger in the later stages of drying will resemble a fracture line until its true nature is recognized by reflected light. A wetting agent added to the final wash bath lessens the risk of these marks.

B.   Faults During Exposure

(1) *Grid cut-off*

Bucky or stationary grid cut-off may arise if the tube is not accurately centered over the middle of the film. It will show as a shading maximum at one side of the film. It may also occur if the focal-film distance does not match the grid radius in which case the effect is balanced at the two sides of the film. Shift across a moving grid rather than in the long axis of the strips may affect one of a stereoscopic pair of films more than the other. Close examination will show a broadening of the grid lines at the expense of the intervals between them if a stationary grid is used.

(2) *Grid lines*

Lines of a Bucky grid may show if exposure is made before or after movement of the grid or from an excessively short exposure in relation to grid speed. It may also come about from a stroboscopic effect of the X-ray pulses.

(3) *Off-center Cone, Tube or Filter*

A cone displaced from its central position under the target or a shift of the tube-cone assembly to one side with respect to the film will result in an area of reduced density which may be obvious if the margin of the defect is sharp. Sometimes only a small part of the X-ray beam is cut off and the variation in density is so gradual that it is not readily apparent. An incompletely inserted filter could give a similar appearance. Here the penumbral unsharpness is large because of the nearness to the target, and the margins will be quite indistinct.

(4) *Heel Effect of Target*

The strength of radiation from the target varies with the angle of reflection. The heel effect is due to a lessened intensity as this approaches the grazing angle. The tube should be orientated to have this effect directed to one end of the table so that symmetry may be preserved. For chest radiography it may be placed so that its reduced intensity exposes the lung apices which require less exposure than the bases. A good demonstration of the magnitude of the heel effect at various angles and distances is given by Fuchs[1].

(5) *Multiple Images*

Double exposure of miniature chest films is sometimes not readily recognized. Elsewhere this fault is obvious. It need not be due to two separate exposures, for movement of the patient may cause a double image. Figure 4 shows an example in which two thumb tacks in the stomach register as four in number because of respiratory motion.

Figure 4 — Double exposure effect from movement. Two thumb tacks in the stomach register as four because of respiratory movement.

(6) *Fog*

Fog arising during exposure is due to secondary radiation and back-scatter. These have been discussed under the heading "Contrast".*

Published in Part I, which appeared in September issue J.C.A.R.

C. Inherent Film Faults

A film could be faulty through a manu-facturing error but in practice this is scarcely ever seen. Examples are holes in the emulsion and other forms of uneven coating. Reference has already been made to a variation in competitive films in their susceptibility to fog from dark room illumination and in their tendency to developer fog. Another fault is a difference in speed of various batches of film. However there are so many larger factors affecting apparent speed that this is seldom of any appreciable importance.

Figure 5 — Overlap density paradox. Where the soft tissues of the great toe cross the middle phalanx of the 2nd toe a fracture is simulated.

D. Miscellaneous Artefacts

(1) *Screen blemishes*

Good screen care is essential for the pre-vention of artefacts. A careless dark room worker can quickly ruin a screen by carrying developer to it on his hands. Where feasible it is good practice to load and unload cassettes in a room separate from the processing room.

The brown stain of developer on screens retards fluorescence and gives light areas on the film. Every screen should have a lead number embedded in it or some other means of identification. The newer screens on the market have an overcoating of protective material which preserves them from con-tamination.

Screens that are dirty or abraded cause light areas in the film — never dark ones. Particular care should be taken of screens that are used for foreign body localization about the orbit. Poor screen contact has already been mentioned as a cause of low definition.

Figure 6 — Overlap density paradox. Mid line basi-occiput flange overlaps posterior arch of C1 to produce an unexpected dark line.

(2) *Overlap density paradox*

The expected summation effect of super-imposed densities does not invariably take place. A paradoxical reversal is occasionally seen along the line of overlap. It is described as the mach[5] effect, and has been interpreted as an optical phenomenon. Figures 5 and 6 illustrate examples of this phenomenon.

(3) *Marker error*

By far the commonest error in the X-ray department is wrong identification of right and left sides from improper marking. The radiologist is at the mercy of his technical staff unless he has a means of knowing which face of the film was directed to the tube. This information which can be obtained from permanent marks on cassettes and cardboard film holders, coupled with the knowledge of whether the particular view was antero-pos-terior or postero-anterior, makes recognition certain even in instances of transposition of

the viscera. Lead numbers embedded in the face of cardboard holders and cassettes serve the purpose well and also permit identification of a particular holder or cassette. The numbers chosen should be ones that can be read properly from only one direction. One should avoid the figures, 1,3,6,8,9 and 0 unless combined with figures 2,4,5 or 7. Alphabetical letters may of course be used if the same precautions are taken.

Figure 7 — Barium spillage artefact. Barium on a gown producing a club-shaped mark with a cross-hatched pattern of the fabric.

(4) *Stereoscopic depth falsification*

If the subject or part of the subject shifts position while stereoscopic views are being taken, a false localization of the depth of various parts may be made. Respiratory movement may cause the lungs to appear to be outside the thorax. A case* is on record in which foreign bodies in the skin of the forehead were falsely localized intracranially because of a slight shift of the skull with respect to the mobile scalp tissues between the two exposures.

(5) *Medical Technical Faults*

In addition to film artefacts there are many which are mainly faults of medical technique. They are described here because their effects are recorded in radiographs.

Personal case.

(a) Opaque media spillage

Barium spilled on a gown or sheet may give rise to confusing shadows in a great variety of shapes. Examination of the radiograph with a hand lens will usually show a fabric pattern. Figure 7 shows an example of this. Lipiodol or other opaque oil makes a smudgy, less well-defined shadow.

(b) Barium mixture faults

There are two faults in proprietary barium mixtures that may cause errors in interpretation. One mixture on the market has a tendency to surface foam when mixed. In a gastro-intestinal examination the bubbles resemble polypi (Fig. 8). Another brand has a suspending agent which renders the mixture sufficiently viscous that bubbles of air are trapped and move only very slowly to the surface.

Figure 8 — Barium mixture fault in a proprietary product. Multiple air bubbles in fundus of stomach and duodenum simulating polypi.

(c) Faulty injection technique

Over-distension of the calyces of a kidney in a retrograde pyelogram with the production of temporary hydronephrosis and backflow into tubules,

veins and lymphatics is a source of danger, for the appearance may be considered pathological. Air bubbles inadvertedly mixed with an opaque medium may resemble polypi in the various organs examined. Excessive syringe pressure when injecting sinus tracts may create new paths in the tissues. Failure to mix the injected material with fluid already in the organ may give variations in opacity suggesting an abnormal condition.

(d) Errors in patient preparation

One should be alert to the possibility of unsatisfactory preparation of the patient for examination. Instructions may not have been followed or if followed may have been inadequate. Food residues in the stomach, failure to take gall bladder tablets, pills or capsules in various stages of disintegration in the digestive tract and faecal residue in the colon are examples familiar to every X-ray department.

Summary

An attempt has been made to list the major faults and virtues of radiographs. Table I of Part I published in an earlier issue lists the factors covered. From time to time new defects crop up unexpectedly. The radiologist should accept these as problems in diagnosis second in importance only to clinical pathology. By close attention to technique most of them will be eliminated and the radiologist's reputation for good work will be as unblemished as his films.

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THE CANADIAN ASSOCIATION OF RADIOLOGISTS

Twenty-fourth Annual Meeting

January 22-25, 1961

Admiral Beatty Hotel, Saint John, N.B.

RESUME

SUNDAY, JANUARY 22, 1961

Council Meeting	9:00 A.M.	Salon F
Council Meeting	2:00 P.M.	Salon F
Entertainment of Members of Council and their Wives	6:30 P.M.	Home of Dr. and Mrs. E. A. Petrie Rothesay, N. B.

MONDAY, JANUARY 23, 1961

Registration — Salon A

Council Meeting	9:00 A.M.	Salon F
Scientific Sessions	2:00 P.M.	Georgian Ball Room
Curling Bonspiel	5:00 P.M.	Heather Curling Club
Cocktails and Dinner	7:00 P.M.	Heather Curling Club

TUESDAY, JANUARY 24, 1961

Registration — Salon A

Scientific Sessions	8:30 P.M.	Georgian Ball Room
Civic Luncheon	12:30 P.M.	Georgian Ball Room
Scientific Sessions	2:30 P.M.	Georgian Ball Room
Annual Meeting	8:00 P.M.	Georgian Ball Room

WEDNESDAY, JANUARY 25, 1961

Registration — Salon A

Scientific Sessions	8:30 A.M.	Georgian Ball Room
Luncheon	12:45 P.M.	Georgian Ball Room
Gordon Richards Memorial Lecture	2:30 P.M.	Georgian Ball Room
Scientific Sessions	3:30 P.M.	Georgian Ball Room
Reception	7:00 P.M.	Georgian Ball Room
Dinner Dance	8:00 P.M.	Georgian Ball Room

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QUARTERLY

EDITORIAL

"THE 90% OPERATION"

In the management of the patient with cancer, the therapy decision should not be made by any one specialist. The radiologist, the pathologist and the surgeon must work together as the core of a therapy "team". If the radiologist sees the patient only after surgery has been done, he is too late to make his full contribution.

It is not our purpose to discuss here which cancers should be treated by radiation and which by surgery. We are concerned with the case where the surgeon and the radiologist are in agreement that radiation may be necessary. In such a case the decision to operate and the nature of the operation are of great concern to the radiotherapist, and to the surgeon alike.

If it be decided that a biopsy is all that is required, it should be a biopsy and no more. The temptation to remove more tissue at the time of this surgical procedure should be resisted. Occasionally, such as in an emergency decompression, a more extensive surgical procedure must be carried out, but this must be done with the knowledge that it will not help the radiotherapist if the surgery is radical. Where no emergency exists, the tumour should not be removed in part, even though it is technically possible. In such a patient, if the surgeon does do an extensive removal because it is technically feasible, the operative report may state that "we were able to get out most of the tumour".

Certain flaws in thinking lead to the so-called 90% operations. The idea exists (and it is often shared by the patient), that taking out most of the tumour decreases the amount of radiation required. In fact, more radiation is required because of the operation and it is more difficult to give. This is due to six factors: a) the required dose is based on the biological type of the tumour and not on the number of cells present; b) the operation may disseminate the lesion beyond the fields of radiation; c) scar does not tolerate radiation well; d) impaired blood supply produces a relative anoxia of the tissues and this tends to protect the tumour against the effects of radiation; e) the stress of a major operative procedure increases the number of possible cancer implants, as has been shown experimentally; f) complications following major surgery may cause postponement of radiation therapy.

The major factor which leads to the "90% operation" is a sincere desire on the part of the doctor to do something for the patient. Having given him an anaesthetic and made an incision, an urge to attack the tumour and to help the patient leads to removal of as much as possible of the accessible disease. The patient may then be told that he is getting radiation in addition to the operation "just to be sure". This is an emotional rather than a scientific approach to cancer treatment, reflecting the feeling that the patient expects the surgeon to do something for him.

The "90% operation" works against the patient's interests and is rarely done in first-rate cancer treatment centres. If all this be true, but not sufficiently appreciated or practised in every day cancer therapy, then the radiologist must say to his surgical colleague, not once but repeatedly: "Let's remember, this cancer should be treated primarily by radiation or primarily by surgery; if you remove most of it and I radiate what's left, we are giving second-rate treatment."

M. N. LOUGHEED, M.D.

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QUARTERLY

EDITORIAL

THE STRUGGLE FOR RECOGNITION

Radiologists should remember that theirs is not the only medical specialty in which there has been a struggle for recognition.

The recent book "Small Patients" by Dr. Alton Goldbloom[1], makes it quite clear that the specialty of paediatrics — and specialists like Dr. Goldbloom — had indeed to fight for a place in the sun among other specialties. Sir Russell Brock[2], whose work in thoracic and cardiovascular research and surgery has made him one of the best known surgeons of our time, spoke with some bitterness in 1955 of the surgeon's struggle for recognition. "By tradition the surgeon was a lower form of life than the physician," he said "and by tradition he tends to remain so in the minds of some."

Perusal of the urologic journals[3,4] shows what seems to the outsider to be an astonishing preoccupation among urologists with the problem of recognition and respect for their specialty. The anaesthesist is well established as a physician with training and skills which have won a place among his colleagues in other activities, but this position has only recently been won in Canada and in the United Kingdom.

These examples do not make a complete catalogue of doctors who feel that their specialty needs and merits more recognition. One must of course add the general practitioner, who inherits a tradition in many ways the oldest and noblest of all the medical branches. The general practitioner quite rightly points out that his work is in a sense a specialty in "family practice" and in many ways is the most difficult and demanding of all.

It is only natural of course that of the large number of specialists in the fields of medicine and surgery some will tend to attract men of higher calibre than others. It would be unrealistic to think that nature would provide for a perfectly even distribution of the attributes of a good doctor among all the branches of the profession. Fortunately the qualities that make a man a good physician are not necessarily those which are essential to a good surgeon, and the ideal general practitioner would not necessarily do well in research. Nevertheless there is a tendency for some of the specialties to achieve recognition within the medical profession by virtue of attracting men of generally higher calibre than others.

What can the radiologist do to promote recognition of his specialty, assuming that recognition is in fact desirable and necessary? To say that he can be more effective by earning recognition as a good doctor rather than by demanding it through the well lubricated channels of "public relations" is to state the obvious. What is perhaps less obvious and needs emphasis is the duty of the radiologist to try to attract to his specialty a high calibre of trainee. It was not very long ago that the ranks of radiology were recruited in considerable proportions from physicians and surgeons with partial disabilities or even a disinclination to endure the rigors of general practice. The radiologist today can make a major contribution to his specialty by taking an interest in promising young men who show some inclination to learn about radiology and train as radiologists; to recruit one good man is a tremendous accomplishment. Just as important, he can discourage men from entering the specialty if he thinks they will not make good radiologists. It is not, unfortunately, uncommon in this country to hear that a man has been turned down by one training center as being an unlikely candidate for post-graduate work in radiology, only to be accepted with alacrity by another center where there is need for help in an overworked department with a high case load and an numerically inadequate professional staff. Surely this is the place where the conscientious radiologist can do much to help his specialty in the struggle for recognition. If he will accept a man for resident training in radiology with the prime motive of training a good man, rather than of securing inexpensive professional help, he will be doing a service to his specialty and to medicine.

J.S.D.

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QUARTERLY

EDITORIAL

THE DIAGNOSTIC RADIOLOGIST'S RESPONSIBILITY TO THE PATIENT

The radiologist's relationship to the patient is complex and in need of personal review from time to time. The strength of western medicine has been the bond of patient-physician relationship and the radiologist's role is to aid both partners in the solution of the medical problem. He has all the responsibilities of a physician, including ultimate responsibility to the patient.

Modern convention has omitted the formal introduction of the patient by the referring physician to the radiologist and at times it has become so loose that the patient feels he is having a "test". The patient is better served if the radiologist acts as a consultant. He must have full clinical information about the case before he can plan the necessary radiographs; he cannot offer an adequate opinion without this information; and he must consult with the referring physician rather than merely report to him, if he is to fully appreciate and evaluate the information of his powerful and elegant diagnostic tool. Personal history taking and examination are often necessary for authoritative diagnosis and the solution of complex problems.

The patient's immediate needs are courtesy and reassurance in a strange setting, and prompt radiography upon arrival in the department is an essential part of management. Delicacy and professional secrecy must be the concern of all the staff of the radiology department. Review of the films by the attending radiologist before dismissal of the patient, if at all possible, insures film quality and a complete examination. The radiologist often becomes the first to accurately diagnose the medical condition and until the referring physician is informed and able to arrange for appropriate treatment, the radiologist may have to care personally for the patient to avoid suffering due to delays in therapy. Not to do so would be to abandon a patient who has been entrusted to his care. Occasionally patients arrive in the department who need medical supervision during the examination, or emergencies may arise during the conduct of the examination. The emergency equipment of the department must always be ready and thoracotomy trays, suction, oxygen equipment, emergency drugs, and trained personnel ready to use them are required.

As the radiologist has accepted the patient in consultation, he must bear personal responsibility to him. Occasionally his evaluation of the case from clinical data and the films is in conflict with that of the attending physician. Almost always such differences are resolved by fuller discussion of the case, and the truth usually emerges. He must be explicit to the attending physician about serious disagreement and he has the right to request that the attending physician seek another physician's opinion. The radiologist should not undertake work that he cannot do well if he has other colleagues easily available in the community who can perform the task better.

Excellent clinical radiography often brings the patient into close relationship with the radiologist. At the end of the studies, the patient usually wishes to know the result even before the referring physician can be informed. Usually the attending physician is the best person to inform the patient about the results of the studies in relation to the entire clinical picture. Prompt reporting in writing or verbally is greatly appreciated by patient and physicians alike and helps to maintain the patient-physician trust which is the basis of best medical care.

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